

SOME EMPIRICAL EVIDENCE ON HYSTERESIS
IN AGGREGATE US IMPORT PRICES

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Working Paper No. 16

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Working Paper Series

Center on Japanese Economy and Business
Graduate School of Business
Columbia University
March 1988

1. Introduction

The 1980's have been marked by enormous swings in the real US dollar exchange rate. Starting in the third quarter of 1980 the real dollar appreciated during 16 out of the 18 subsequent quarters leading to a cumulative real rise of almost 40 percent. The turning point, which came in February 1985, was followed by a period of steady depreciation which has lasted more than two years. Depending upon the particular real exchange rate index chosen, between 75 and 100 percent of the real appreciation had been reversed by second quarter 1987.

This dollar cycle, the magnitude of which is entirely unprecedented by post-war experience, has had rather puzzling effects on import prices. Historically, movements in the real exchange rate have been passed through approximately one-for-one to the real price of imports. The rising dollar of the first half of the 1980s did lead to lower real prices of imported goods, however, the two-year fall in the exchange rate has lead to only a slight increase in the real import prices. This puzzling behavior is interesting in itself. It takes on added importance, however, in that the sluggish rise of import prices has contributed to the persistence of the US trade deficit.

The failure of import prices to rise has been frequently noted in the business press. The usual explanation offered is that import prices have not risen in the face of the falling dollar because foreign firms have been cutting profit margins. This, of course, is not by itself an explanation -- it is an implication. If costs rise and prices don't, profit margins are squeezed. What we need is an economic explanation of why foreign firms have found it optimal to not pass the depreciation through to higher prices.

Hysteresis is defined in the American Heritage Dictionary as, "failure of a property change by an external agent to return to its original value when the cause

of the change is removed". One explanation of the recent behavior of US import prices is that the unprecedented magnitude of the dollar cycle has resulted in hysteresis. This paper empirically investigates the hypothesis that hysteresis has occurred in aggregate US non-oil import prices.

The possibility that large exchange rate shocks induce persistent real effects has implications for both the real and monetary sides of international economics. For instance if temporary exchange rate fluctuations have persistent trade effects then the standard welfare analysis of flexible versus fixed exchange rate regimes would have to be re-thought. Indeed, Bean 1987 finds evidence that the 1978-81 sterling overvaluation had negative hysteric effects on British export performance. Additionally, Baldwin and Krugman 1986 shows that import hysteresis can theoretically lead to exchange rate hysteresis, implying that the long run equilibrium exchange rate may be path-dependent.

On the trade side, hysteresis in imports might strengthen or weaken arguments for temporary, cyclical protection. Also Dixit 1987 points out that in hysteretic models pricing below long run average cost is a normal, non-predatory response to the falling dollar. This casts doubts on the usefulness of the ITC's definition of dumping. While these theoretical and policy ramifications of hysteresis are interesting, they are not addressed in this paper.

This paper empirically investigates the hypothesis that hysteresis has occurred in US aggregate import prices. We review evidence based on standard ad hoc, pass-through equations, as well as evidence based on two structural models (the beachhead model, Baldwin 1986 and the bottleneck model, Foster and Baldwin 1986) which could account for the hysteretic behavior of import prices.

Briefly, the beachhead model asserts that the prolonged overvaluation prompted many new foreign firms to enter the US market (establish marketing "beachheads"). Not all of these new firms found it optimal to exit in the face of the falling dollar due to supply-side factors (sunk investments) or demand-side factors (US

consumers acquiring a taste for imports). The presence of these new entrants led to a persistent increase in the degree of competition in the US market for imports. The increased competition, in turn, led to lower profit margins.

The bottleneck model focuses on the existence, and irreversibility, of capacity constraints ("bottlenecks") in the marketing, distribution and servicing networks of importers. According to the model, importers took advantage of a dollar appreciation by expanding capacity and lowering prices. Thus at the peak of the dollar cycle, importers were operating at their capacity constraints. The turn around of the dollar was not fully passed through to prices since the cost increases stemming from the dollar fall were partially offset by an alleviation of the marketing bottlenecks.

The prima facie case for import price hysteresis is presented in the second section. Section three considers possible theoretical sources of the shift. The next section examines a structural model (the beachhead model, Baldwin 1986) that could account for hysteresis. The model is presented and a number of testable hypotheses are derived and empirically evaluated. The fifth section considers an alternative model (the bottleneck model, Foster and Baldwin 1986) which could also explain the puzzling behavior of import prices. The model is presented and then tested empirically. A summary of our findings and directions for future work are provided in the conclusion.

A direct test of the beachhead model would require time series data on the number of varieties of imported goods and their close substitutes, as well as a functional form for the dependence of the demand elasticity on the number of varieties. Direct testing of the bottleneck model would require data on distribution capacities. These tests are most likely to be fruitful on industry level data.

It is our intention here to focus on aggregate macro data. This choice may be justified on two grounds. First hysteresis in aggregate import prices could be

part of the explanation of the persistence of the US trade deficit. It is therefore useful to test the hypothesis carefully on aggregate data. Secondly, it would be convenient to have a simple micro explanation of the puzzling behavior of aggregate import prices.

To sum up the results, we find strong evidence that the pass-through relationship has shifted in the 1980s. Examination of the time pattern of the forecast errors and the residuals of standard pass-through equations, in addition to formal structural break tests, lead us to this conclusion. The shift, however, is also consistent with a long-lived but not permanent change in the pass-through relationship. A hysteretic shift is one that persists after the cause of the shift has been removed. Since by many calculations the real dollar was still overvalued by 10-30 percent in mid-1987 (Krugman and Baldwin 1986), it is perhaps too early to distinguish between long lags and true hysteresis.

Evidence on the two structural models of hysteresis is less decisive. While the the evidence provides some preliminary support of both models, which model looks better depends upon which real exchange rate measure is used. The beachhead model does better on a measure based on wholesale prices. The bottleneck model does better on a consumer price based measure. We conclude that neither model can explain all the data, however both are likely to be part of any complete accounting of import price behavior.

2. The Prima Facie Case for Hysteresis

Before turning to structural models or formal econometrics, we examine some informal arguments for a shift in the pass-through relationship. The simplest and perhaps most convincing case for the shift can be made by comparing the movement of exchange rates and import prices during the pre- and post-1980 periods. A graphic way of doing so is to use the historical relationship between the exchange rate and import prices to forecast post-1980 import prices and then examine the forecast

errors. To this end we regress the log of real import prices on the log of the real exchange rate and a constant using pre-1981.3 data (this date was chosen since it is only one year into the dollar cycle -- long before the dollar was generally considered overvalued). The estimates are then used to forecast prices through 1986 and the forecasted values are plotted against the actual import prices. We perform this exercise for the various price and production cost measures. The results are found in figures 1 through 4.

The simulated values in figure 1 are generated from the regression of the log of the real import prices on the log of the real exchange rate and a constant. Specifically the real import price employed is the US GNP deflator for non-oil imports divided by the US wholesale price index (WPI) for manufactured goods, and the real exchange rate index is the ratio of an import-weighted index of foreign manufactured goods WPIs to the US WPI adjusted by an import-weighted nominal exchange rate index. Figure 1 shows that the historical relationship tracks the actual import prices relatively well for the first few quarters of the cycle. However, starting in mid-1982, the historical relationship overpredicts prices for 15 consecutive quarters. Figure 1 clearly depicts a *prima facie* case for hysteresis. According to the hysteresis interpretation, the unprecedented magnitude of the dollar overvaluation (or anticipation thereof) altered the pass-through relationship. This shift does not appear to be fading despite the passing of the exchange rate shock.

Figure 1 can be faulted, however, in that it allows for no lags in the pass-through relation. Since most researchers include lags of the exchange rate in the pass-through relationship, we allow for this possibility in figure 2. Specifically we repeat the procedure used to produce figure 1 but this time include 8 lags (quarterly data) of the log of the real exchange rate as regressors. A polynomial distributed lag structure is imposed. The results are plotted in figure 2. Adding in the 8 lags does not change the general conclusions we drew

from figure 1. Rather the errors become even more pronounced. This may be due to the short period of estimation (1977.1 to 1981.3).

The data used in constructing these figures have many shortcomings. For instance the exchange rate index includes only the G-10 industrialized countries, leaving open the possibility that the pattern results from the exclusion of the newly industrializing countries. Moreover, a significant portion (between 10 and 20 percent) of the US non-oil imports are commodities, so that a manufacturing-based production cost proxy can be expected to perform poorly during periods of large commodity price swings. To partially address such concerns, we repeat the procedure using an alternative measure of the real exchange rate.

The next two figures repeat the figure 1 and 2 procedure using a real exchange rate measure based on foreign consumer prices indices (CPIs). Consumer prices are a poor proxy for production costs (since they include non-tradables), however, they are available for a wider range of US trading partners and for longer time periods than are wholesale prices. The measure of foreign prices we use here is the Federal Reserve Board's foreign production cost proxy, as reported in Helkie and Hooper 1986. The proxy is constructed from import-weighted CPIs from the G-10 countries and eight LDCs (Mexico, Brazil, Taiwan, Singapore, Hong Kong, South Korea, Philippines and Malaysia). The real exchange rate index is created by converting this foreign production cost proxy into dollars using an import weighted nominal exchange rate index and dividing by the US GNP deflator. The real import price is the non-oil import price deflator over the US GNP deflator.

Figure 3 shows the simulated pass-through without lags. Here again we see that import prices fell with the rising dollar but failed to rise post-1985. As a result, import prices are too low in 1986 and the second half of 1987. The shift in figure 3 however differs from that in figure 1. Figure 3 indicates that the pass-through was muted in that the prices fell somewhat less than expected and have risen much less than expected. The inclusion of 8 lags does not change the

substance of this conclusion, as figure 4 depicts. What is common to both sets of figures is that the rising dollar was passed through to lower import prices, but the falling dollar has resulted in very little price rise.

The results of figures 1 through 4 are not surprising. Out of sample predictions are usually increasingly wrong for macroeconomic relationships. An alternative is to look at the residuals for regressions run on data from the whole period. Figures 5 through 8 correspond to figures 1 to 4 but are run on data from the whole period. The regression errors are naturally less pronounced than the forecast errors, however the patterns of the residuals are roughly congruent with those of the forecast errors.

In figure 5 the fitted values overpredict in 14 out of the 23 quarters of the dollar cycle (1980.3 to 1986.2), including 11 of the last 14 quarters. Allowing for lagged exchange rate effects in figure 6 does not change the general pattern. Again the fitted values overpredict 14 out of 23 quarters (7 of the last 12). The regressions run on CPI based data present a residual pattern similar to those in figures 3 and 4. Allowing for lags, the relationship predicts the fall in prices during the dollar upswing quite well but fails to account for the slow import price rise post-1985.

While the real form of the pass-through relationship (i.e., real import prices and real exchange rates) is preferable from a theoretical standpoint, the nominal relationship has been more important in the existing empirical literature. To facilitate comparison of our results with this literature we regress a nominal foreign production cost proxy (based on the CPI data described above) on the nominal import prices. The results are found in figure 9. Clearly this figure basically confirms the conclusion of the previous eight figures.

In summary, the time pattern of the forecast errors and regression residuals discussed above plainly suggest that there has been a change in the link between US non-oil imports prices and the exchange rate. In figures 1, 2 and 5 the error

pattern can be interpreted as a once-off shift in the relationship caused by the prolonged overvaluation. The hysteresis hypothesis comes through perhaps even more starkly for the CPI-based data. However this data seems to indicate that the shift coincided with the turn around of the dollar. We take this evidence as sufficient to tentatively assert two related stylized facts: 1) import prices fell in response to the rising dollar but have risen less than expected in response to the falling dollar, and 2) import prices in 1986 and 1987 are lower than the historical pass-through relation would predict.

Structural break tests

We now turn to more formal testing of the hysteresis hypothesis. In a time series regression a hysteretic shift in the pass-through relationship will look like a structural break. Therefore the next type of evidence we examine is a series of likelihood ratio tests for structural breaks.

Clearly looking for structural breaks in time series data constitutes a very blunt test of the hysteresis hypothesis. The break could stem from a wide range of causes that have nothing to do with hysteresis. Moreover there is no reason to expect hysteresis would imply a once-off shift in the relationship. Nonetheless the tests are important in that a failure to find resounding evidence of a structural break would cast more than a little doubt on the validity of the hysteresis hypothesis. In a sense this exercise is nothing more than a formalization of the assertion that the regression errors in figures 5 through 8 are statistically larger in the post-break period than in the pre-break period.

Table 1 lists the results of likelihood ratio tests for structural breaks in pass-through equations. There is no universally accepted standard pass-through equation. To account for this, the tests are performed on a variety of fairly representative, ad hoc pass-through equations (the exact equations are listed at the bottom of the table). Since there are unavoidable data problems, the equations

are also tested on a variety of data sets and a variety of data transformations. The import prices and exchange rates used in table 1 regressions are identical to those used in figures 1 through 8 described above. Lastly since it is not possible to formally identify the break point, tests are performed for a variety of break points ranging from 1980:3 to 1985:1.

Table 1 presents strong evidence that a structural break occurred in the pass-through relationship sometime in the first half of the 1980s. The different data types are listed across the top of the table, while the different formulations are listed on the left hand side. Every cell of this matrix indicates a combination of a pass-through equation and data. In each cell are listed the various break points. A double star indicates that the no-break hypothesis is rejected at the 99.5 percent significance level. A "na" indicates that the test could not be performed. Since every test that could be performed rejected the no break hypothesis at the 99.5 percent level, we can be rather confident that something has changed in the pass-through relationship in the 1980s.

As they stand, the two stylized facts from the figures and the structural break tests are consistent with hypothesis that hysteresis has occurred in the macro pass-through relationship. While there is certainly room for alternative explanations of these stylized facts, the hysteresis hypothesis cannot be rejected out of hand as an empirically empty theorizing. Moreover, these stylized facts will, perforce, be reflected in any econometric estimation of the pass-through relationship.

3. Possible Sources of Discontinuous Pass Through Behavior

The last section argued that the relationship between US import prices and the exchange rate has shifted sometime in the 1980s. Ignoring lags and aggregation problems, the pass-through relationship could shift due to one of three factors if

firms operate at the point where expected marginal cost equals expected marginal revenue. Rearranging this first order condition, we get the well known relationship between marginal costs, c^* , prices, p , and the perceived demand elasticity, ϵ : $E\{p[1-(1/\epsilon)]\}=E\{c^*\}$, where variables are measured in dollars. The dollar denominated marginal cost of foreign firms depend on the exchange rate. We can use this relationship to identify the three possible sources.

The first conceivable source of the shift is a reduction in the cost markup, or profit margin, $[1-(1/\epsilon)]$. Note that the margin depends only on the perceived elasticity, ϵ . Consequently a fall in the profit margins must be due to an increase in the perceived elasticity. The second source is from the relationship between marginal costs and the exchange rate. If the dollar marginal costs of foreign firms depend upon the exchange rate in a discontinuous manner then the pass-through relationship could be discontinuous.

The third source of shifts are the expectations themselves. As was clear from the figures, the shift in the pass-through relationship has persisted or worsened well into 1987. Presumably any expectations based model would assert that foreign firms had expectation of the exchange rate level that significantly differed from the observed level. While such a explanation seems implausible, it is certainly a possibility. We shall not discuss expectations based models here. It is worthwhile to note, however, that the figures in the last section suggest that firms reacted differently to the final run up of the dollar which many economists believe to have been a rational bubble (Gavin 1986).

4. The Beachhead Model

The beachhead model has two versions; one concentrates on supply side factors, the other on demand side factors. In both versions a large overvaluation (or anticipation thereof) prompts the entry of new foreign firms into the US market.

The net effect is to increase competition in the US home market for imported goods. While the models differ in their accounts of why not all of the newcomers exit with the passing of the exchange rate shock, the lasting change in market structure is the ultimate source of hysteresis in both models.

Chamberlain 1933 argued that an increase in the number of varieties available increases the perceived elasticity of demand for each variety. The persistent increase in the number of foreign firms therefore entails a persistent increase in the demand elasticity faced by foreign firms. This in turn leads to a persistent decrease in profit margins. Hysteresis in import prices is the result. While the Chamberlain framework is convenient, an increase in the number of firms leads to lower profits margins and lower prices in almost any model of imperfect competition. Thus any setup that leads to a persistent increase in the number of firms is likely to result in price hysteresis.

Supply-side Hysteresis

The first version (Baldwin 1986, 1987) relies on the existence of market entry costs that are sunk and durable. We assume that the production costs of foreign firms are homogeneous of degree one in output and the exchange rate. In addition to the direct production costs, firms must incur a fixed cost, F , in order to sell in the home market. This cost, which is essentially a market entry cost, is meant to reflect the costs of the firm- and market-specific assets that are required to sell in a new market. For example F could represent the costs of setting up a distribution and service network, of training workers and managers, and of bringing the product into conformity with domestic health and safety regulations. While some of these costs may be recouped if the firm ceases to sell in the country, some of them are likely to be sunk costs.

Furthermore, we assume that these sunk assets require maintenance. In order to continue selling in the home market, firms must incur a fixed maintenance cost,

G, in each period. If the maintenance is not done, the sunk asset disappears, i.e., the firm exits. For example, if F represents the cost of a brandname introduction advertising blitz, G would represent the brandname maintenance advertising. For simplicity, we assume that both F and G are incurred in the US and so are independent of the exchange rate. It might seem more sensible to assume that not all of the sunk asset disappears when the firm exits. In this case the re-entry costs would be below the entry costs. This consideration would complicate the analysis without providing any compensating insight.

In an imperfectly competitive world with these sunk and durable assets, consider the effects of an exchange rate shock. A prolonged overvaluation of the dollar would increase the competitiveness and profits of foreign firms. The prospect of greater profits would in turn encourage more foreign firms to acquire the assets necessary to sell in the US. Because the investment is sunk and durable, not all the new entrants will exit when the overvaluation passes.

Since firms are making intertemporal decisions, the exact nature of firms' exchange rate expectations are crucial to the mechanics of the model. Baldwin 1986 and 1987 consider perfectly anticipated exchange rate overvaluations. This assumption is meant to capture the notion that firms may have anticipated a prolonged overvaluation of the dollar due to persistent changes in US monetary and fiscal policy in 1980. This approach may be criticized in that it fails to allow for the stochastic nature exchange rates.

Baldwin and Krugman 1986 extends Baldwin 1986 by solving the entry problem for firms facing an independently and identically distributed (iid) exchange rate. Moreover it shows that industry-level hysteresis will result in aggregate hysteresis under plausible assumptions, and demonstrates that for a very simple exchange rate model hysteresis in imports leads to hysteresis in the exchange rate.

While the assumption of an iid exchange rate greatly simplifies the problem, many economists feel that empirically the exchange rate is best modelled as a

random walk (Meese and Rogoff 1985). It is therefore important that Dixit 1987a and 1987b solve the entry problem in a framework similar to the beachhead model allowing for Brownian motion (continuous random walk) of the exchange rate. In all of these models large exchange rate shocks have hysteretic effects.

In summary, the existence of sunk, market entry assets implies an asymmetry between firms' the entry and exit conditions. Due to this asymmetry the entry and exit conditions do not uniquely determine the equilibrium number of firms but rather a range within which the number of firms must lie in equilibrium. A sufficiently large overvaluation (regardless of which stochastic process it follows) could shift the economy to an equilibrium with more foreign firms than prior to the exchange rate shock. The net effect would be to leave the home market structure more competitive. This lasting change in the market structure forces a lasting reduction in profit margins.

Demand-side Hysteresis

In the previous model the persistent change in the number of firms was due to supply side considerations. A large exchange rate shock could also have persistent trade effects via a demand side channel. This version of the beachhead model relies on imperfectly informed consumers. Suppose that US consumers are uncertain about the quality of foreign goods they have never tried. The economics of such goods (so-called experience goods) have been widely studied (Schmalensee 1982, Grossman and Shapiro 1986). The effect of this demand structure is that new entrants face an initial period of low demand during which consumers become familiar with their product. Suppose furthermore that firms must incur some sunk costs in order to sell in the US. In this framework, a firm will enter the domestic market only if it anticipates that the discounted sum of operating profits in the introductory and established periods will cover its sunk costs.

It is easy now to see how this combination of fixed costs and demand structure

can lead to hysteresis. An overvaluation means higher operating profits for prospective entrants during the overvaluation. Other things equal, this will allow more foreign firms to cover the fixed market entry costs. When the overvaluation passes, the dollar value of foreign marginal cost rises. However, since domestic consumers have tried their products, foreign firms also face higher demand curves. Consequently not all of the new entrants will be forced out.

Essentially the overvaluation plays the role of a costless introductory pricing scheme which leads US consumers to become familiar with new foreign products. This permanent change in the information sets of US consumers implies that the market can support a higher number of foreign firms after the overvaluation than before the overvaluation.

Another variation of demand side hysteresis focuses on US retailers rather than US consumers. Suppose that US consumers are perfectly informed about the quality of foreign goods, however US retailers are imperfectly informed about consumers' tastes for new goods. If there is a fixed cost to retailing a new product, then this version becomes isomorphic with the experience-goods model discussed above. The difference is in that here, the overvaluation induces the retailers and not the consumers to learn.

In both versions of demand side hysteresis, an exchange rate shock may cause a persistent increase in the number of varieties of imported goods which in turn induces a persistent reduction in profit margins.

Testing the Beachhead Model

Before turning to the data directly, we first review some relevant existing empirical literature on pass-through behavior. The beachhead model is comprised of two assertions: first that an exchange rate shock can alter the US market structure faced by foreign firms, and second that market structure affects the pricing behavior of foreign firms. While there are no direct empirical

investigations of the first assertion, there have been several studies done on the second. Dornbusch 1986 is the seminal article. In that paper he uses disaggregated macro data and some industry data to argue that market structure affects pass-through behavior.

Mann 1986a, 1986b and 1987 as well as Feinberg 1986 and Foster 1986 examine pass-through behavior by industry. These studies generally support the second assertion of the beachhead model. Feinberg finds weak evidence of a negative relationship between industry concentration and price responsiveness to the exchange rate. He finds somewhat stronger evidence of an inverse relationship between price responsiveness and the capital-sales ratio. Foster finds that pass-through elasticities have been falling in most industries throughout the 1980s. Mann's work points out 1) that pass-through behavior differs greatly across industries and 2) that the extent of the shift in the pass-through relationship during the 1980s dollar cycle also differs across industries. Mann does not formally link these differences to industry characteristics. However she notes that the shift was greatest in industries where the industry-specific real exchange rates moved the most, lending general support to the thesis that the dollar cycle itself was responsible for the shift in the pass-through equation.

Some Testable Implications

The first implication of the beachhead model concerns the timing of the shift in the pass-through relationship. Whether we model the exchange rate process using the perfect foresight, iid or random walk assumption, we come to the conclusion that the new entrants should have started entering sometime during the dollar upswing. Consequently we can write:

Hypothesis 1: Profit margins should have begun falling sometime between 1981 and 1985.

Assuming that firms act as if the exchange rate is iid or a random walk, then

entry and the attendant fall in the profit margins should have ceased with the dollar turn around. Thus the profit margin should follow an S-shaped curve with the first curve coming early in the dollar rise and the second curve coming with the dollar turn around. If firms had perfect foresight of the exchange rate, all firms that were going to entry would do so as quickly as possible. This implies that the profit margins should have stopped falling sometime in the rising phase of the dollar cycle. Lastly if firms' expectation of the exchange rate were formed adaptively they might have continued entering even after the turn around. It seems reasonable to suppose that adaptive expectations would be formed using the current and no more than 8 lags (quarterly data) of the exchange rate. Summing up the implications of each of these models, we note:

Hypothesis 2: Profit margins should have stopped falling no later than early 1987.

Examining figures 1 through 8 provides contradictory evidence on hypothesis 1 and 2. The figures based on the manufacturing WPI data, especially figures 1 and 2, tend to confirm the hypotheses. The historical pass-through relationship begins to overpredict in the early 1980s as we would expect if profit margins shrunk. The relationship seems to shift slowly until the end of 1984 or early 1985 and then stops shifting. This tends to confirm hypotheses 1 and 2.

The CPI based figures, however, tend to indicate that the beginning of the shift occurs with the turn around of the dollar. In figure 4, for instance, it appears that the shift begins in early 1985 and continues to widen into 1987. This pattern tends to refute the hypotheses.

Testing for Parameter Constancy

More formally we can test hypotheses 1 and 2 by testing for a parameter shift in a pass-through equation. In order to have confidence in our formal testing however we must have a model of the pass-through relationship in which the perceived demand elasticity (and therefore the profit margin) is identified. The

ad hoc equations discussed in table 1 do not meet this requirement; ad hoc equations are useful in testing for structural breaks but not in testing for specific shifts in structural parameters such as ϵ . In particular there is no microeconomic justification of the lags in the ad hoc equations. We cannot therefore be sure of the relationship between the point estimates and ϵ .

A Micro Model of Lags in the Pass Through Equation

In the appendix we formally derive a pass-through equation in which lagged responses and expectations are explicitly accounted for. In the model monopolistic foreign firms are faced with a delivery lag. The production decision occurs at the beginning of period t before the realized value of the exchange rate, e_t , is known. Moreover, we assume that output produced in period t does not reach the market until period $t+n$. The problem of the firm is to choose production in each period in order to maximize the expected present discounted value of profits.

Clearly firms will produce at the point where the discounted expected marginal revenue in period $t+n$ equals expected marginal costs in period t . Aggregating across firms (which face delivery lags of various lengths) produces a pass-through equation in which today's import price index depends on past exchange rates. The pass-through equation we estimate is (see appendix for notation):

$$(1) \log(P_t) = \log(\lambda \prod_{j=1}^e \left[\frac{\Omega^j}{(1 - 1/\epsilon^j[m_t^h])} \right]^{\theta^j}) + \sum_{i=0}^N \alpha_i \log(C_{t-i}) + u_t$$

The constant term (the first term on the right hand side of the equation) is the parameter we are most interested in. As (1) shows, the constant term is proportional to the average profit margin. The profit margin of a firm j ,

$$\left[\frac{\Omega^j}{(1 - 1/\epsilon^j[m_t^h])} \right], \text{ depends upon the perceived demand elasticity faced by the firm,}$$

ϵ_t^j . According to the Chamberlain assertion, this elasticity is a function of the number of firms in the industry, m_t^h . The beachhead model predicts that this number can be changed by an exchange rate shock. To allow for this m_t^h has a time subscript. The appendix gives the exact definitions of Ω^j , α_i , u_t , λ as well as P_t and C_t .

The perfect foresight assumption implies that m^h should jump up in the early 1980s, forcing up ϵ^j at the same time. In equation (1), this jump would look like a once-off decrease in the constant term. Table 2 presents estimates of the delivery lags equation allowing for an intercept dummy beginning at a variety of points between 1980.3 and 1985.1. Equations are estimated allowing for a maximum lag of 3, 4 or 5 quarters (i.e., $N=3, 4$ or 5). The equation is run on both the CPI-based and WPI-based marginal costs proxies.¹

Table 2 shows that in most cases the estimated constant term (and therefore the profit margin) falls as predicted. In five cases the constant term increased after the break point but the increase is significant in only one case. This observed fall in profit margins is consistent with the implications of the beachhead model (NB: we expect type-1 errors once in 20 tests). Table 2 can therefore be said to provide support for the model. It is important to note, though, that such a drop in the estimated constant term is consistent with a large number of alternative models. In other words, this test of the beachhead model has very little power against alternatives. As always, all we can say is the data is not inconsistent with the model.

Table 2 may be criticised for restricting the profit margin shift to be of the once-off type. Given the heterogeneity of industries and the possibility of other expectations processes, it might seem more sensible to allow the profit margin to shift over time. To allow for this, we estimate equation (1) with $N=3$ allowing the profit margin to vary over time according to a fifth order polynomial (a fifth order polynomial allows for a close fit of the S-shaped time path of the profit

margin predicted by a random-walk exchange rate process). Thus we estimate

$$\log(P_t) = k + \sum_{i=0}^3 \beta^i \log(C_{t-i}) + u_t, \text{ where } k = c + \sum_{j=1}^5 a^j (\text{time})^j. \text{ This is estimated on}$$

both the CPI and the WPI data. The resulting time path of k (which is proportional to the log of the average profit margins) are plotted figures 10 and 11 from 1977.1 to 1986.2. In both figures the profit margins are still shrinking in 1986, which presumably implies that the market was becoming increasingly more competitive even into 1986.

While these time paths are not directly inconsistent with hypotheses 1 and 2, they are somewhat detrimental to the beachhead model. The model predicts a close tie between profit margins and the number of firms. The conclusion that foreign firms were continuing to enter the US well into 1986 is somewhat contrary to the anecdotal evidence in the US business press.

Implications for the Import Volume Equation

While the presentation of the beachhead model stressed the impact of the dollar cycle on the import pricing equation, the model also has implications for the import demand equation. For instance, we might expect that the increased number of varieties might shift out the aggregate import demand equation synchronous with the pass-through shift. Unfortunately, it is not possible to make strong predictions since the implications for the volume equation are very sensitive to modelling issues.

To take an example, consider a market with homogeneous goods and Cournot behavior. In this case the first order condition of the firm is: $p = (\frac{1}{1-S/\epsilon})c$, where p , S , and c are the price, market share and dollar marginal cost of a typical foreign firm. In this setup the entrance of additional firms decreases S and so leads to lower profit margins but it does not affect the demand curve. We should therefore not anticipate that a persistent change in market structure would cause a

shift in the relationship between relative prices, income and the volume of imports at an industry level. If most industries approximate this structure, then we should not expect a shift in the aggregate volume equation.

On the other hand, if we modelled the industry demand structure with the Spence-Dixit-Stiglitz model the industry wide demand equation depends upon the number of firms as well as price and income. Clearly this model would lead us to expect an aggregate demand shift synchronous with the price equation shift. This leads us to conclude that the beachhead model makes no strong predictions about shifts of the volume equation. What we can say is:

Hypothesis 3: If there is a shift in the volume equation, it should be synchronous with the pass-through shift, and it should cause the historical relationship to underpredict import volume.

Figure 12 shows the regression residuals from a standard non-oil import volume equation. The log of import volume is regressed on the log of US GNP and the log of current and 8 lagged values of the import prices relative to the GNP deflator (the real price lags are constrained by a third order polynomial distributed lag structure). Figure 12 seems to indicate that there has been no shift in the aggregate import demand equation.

5. The Bottleneck Model

The second model we considered is the bottleneck model (Foster and Baldwin 1986). This model focuses on a different aspect of marketing, distribution and servicing assets. As in the beachhead model we assume firms must incur some market entry costs. Examples of such costs are distribution networks, training of sales and service personnel and establishment of service centers. In the long run it seems reasonable that these marketing and distribution assets are fully adjustable and subject to constant returns to scale. However we might expect that not all of the factors involved in distribution are instantaneously adjustable. That is to

say firms face a distribution capacity constraint (marketing bottleneck) in the short run.

With constant returns in the long run but some factors fixed in the short run, firms clearly faces diminishing returns in the short run. Moreover since the diminishing returns stem from the fixity of distribution capacity, we might expect that the diminishing returns occur only at levels of sales that exceed capacity.

An extreme version of the capacity constraint, which is common in the industrial organization literature (e.g. Dixit 1980), is depicted in figure 13. Here firms are assumed to have a constant marginal cost of production and distribution and a constant marginal costs of capacity expansion. The result is a step function for total marginal costs where the discontinuity occurs at capacity, K .

The height of the step depends upon the number of periods the firm expects to use the additional capacity. If it anticipates using the additional capacity forever, the height of the kink is rA , where r is the constant discount rate and A is the unit expansion cost. For shorter usage periods, the height will be greater. Prices and costs are measured in dollars in figure 13. An exchange rate appreciation will therefore shift down the marginal cost curve but not will not affect the marginal revenue curve.

If the exchange rate appreciates enough, firms will be led to the point where they will choose to expand capacity. Figure 14 shows this situation. Marginal cost curve mc^0 is drawn so that it corresponds to the exchange rate e^0 where the firm is on the brink of expanding. The price will be p^0 . If the exchange rate continues to rise to e' the firm will expand capacity from K^0 to K' , shifting the marginal cost curve to mc' . As import sales and capacity expand the appreciation will be passed through to lower prices in a continuous manner, lowering the price to p' . This continuous relationship between the exchange rate and prices will cease upon reversal of the appreciation.

When the exchange rate depreciates to e'' , the marginal cost curve shifts up to mc'' . Initially the exchange rate rise has no effect since the firm remains capacity constrained. In other words, the rise in marginal costs due to the depreciation is entirely offset by the diminishing returns. Consequently there will be no change in output, and price will remain at p' . It is not until the exchange rate rises to a level like e''' (which corresponds to mc''') that the depreciation will be reflected in a higher import price. At e''' the price will be p''' and output will fall to Q''' .

Plainly, marketing bottlenecks result in discontinuous pass-through behavior. Due to capacity constraints, total dollar marginal costs are a discontinuous function of the exchange rate. Since the behavior of import prices is governed by the equality of marginal revenue and marginal costs, the pass-through of exchange rates to import prices is discontinuous.

The discontinuity predicted by the model is not a simple asymmetry. The discontinuity is path dependent. In the figure 14 example, a rising dollar led to lower prices but a falling dollar did not raise prices (at least initially). However, if due to a previous fall in the exchange rate, the firm was starting from a situation depicted by mc^0 in figure 15, the asymmetry would be reversed. Here an appreciation would be absorbed by the kink (mc' for instance), while a depreciation would be passed through (mc'' for instance) to a higher price, p'' .

This firm level reasoning must be modified when addressing aggregate relationships. Clearly some firms may face no marketing bottlenecks so in the figure 14 example the exchange rate change from e' to e'' would entail a reduced aggregate pass-through rather than no pass-through. Those firms which are capacity constrained should not raise their prices. Those which are unconstrained should. This leads us to formulate our next hypothesis.

Hypothesis 4: The shift in the pass-through relationship should involve a period of reduced pass-through that starts with the turn around of the dollar.

Once the exchange rate falls enough to alleviate all bottlenecks, there is no force to mute the pass-through of exchange rates. This gives us:

Hypothesis 5: The end of the shift is not precisely predicted by the model.

However once the shift ends, the pass-through elasticity should return to its pre-shock level.

Despite the return of the pass-through elasticity to its original level, hysteresis has occurred. The irreversible capacity expansion shifts the exchange rate at which the bottlenecks will become binding.

Since the economics of the bottleneck model involves no demand side considerations, there is no reason to expect that the import demand equation should shift. This conclusion implies :

Hypothesis 6: There should be no shift in the import demand equation as a result of the shift in the pass-through relationship.

The bottleneck model involves a reduction in the pass-through elasticity while some firms are capacity constrained. The net result is a temporary reduction in the pass-through elasticity but a permanent shift in the relationship between the level of the exchange rate and the level of prices.

The time patterns of the forecast errors and regression residual shown in figures 1 through 8 provides contradictory evidence on hypothesis 4. As noted above, the shift appears to occur during the rising dollar in the WPI data, but at the turn around in the CPI data. Thus the WPI data (especially figure 1 and 2) seem to reject hypothesis 4 while the CPI data (figures 3, 4, 7 and 8) seem to validate it. The CPI data indicates that the shift is still occurring, so that it is too early for evidence on hypothesis 5.

The evidence in Foster 1987 comes to bear here. Foster finds a pronounced trend toward lower estimated pass-through elasticities across time, at least for the aggregate pass-through relationship. If we use the bottleneck model to interpret Foster's regressions, we find some support for hypothesis 4.

According to the bottleneck model, there was a structural break in the pass-through elasticity beginning in 1985. In particular there was a reduction in the pass-through elasticity. If this were true, but a regression were run restricting the elasticity to be constant across the whole period, then the estimated elasticity would be a complicated weighted average of the two sub-period elasticities. When Foster runs regressions on samples starting at progressively later dates, he is essentially increasing the weight put on the lower post-1985 elasticity. While there are alternative explanations for Foster's results, they certainly are not at odds with hypothesis 4.

Hypothesis 6 is concerned with the impact of bottlenecks on the volume equation. As discussed above, figure 12 indicates that there has been no pronounced shift in the import volume equation. This is consistent with hypothesis 6.

6. Conclusion

This paper finds strong evidence that the pass-through relationship has shifted in the 1980s and that the nature of the shift is not inconsistent with the hysteresis hypothesis. Results on specific structural models, the beachhead and bottleneck models, are less conclusive. The data tends to support both models, but neither by itself can provide a convincing accounting of all the evidence. We conclude that we have failed to find a single, simple micro story that can fully account for the puzzling behavior of the macro data. As a result we conjecture that both models are likely to play a role in any complete accounting of macro import price behavior.

Future Research

This paper contains a number of lessons for future research. The first involves the nature of structural models which might account for the shift. Any

explanation must focus on an economic factor causing firms to find it optimal to not pass the depreciation through to higher prices. In particular the business press assertion that import prices have failed to rise because foreign firms have been cutting profit margins is incomplete.

The second concerns future empirical work. Clearly more precise tests of the structural models require industry level data. Moreover this paper points out that hysteresis in import prices involves a lasting change in the parameters underlying the equilibrium relationship between import prices and the exchange rate. In a time series estimation of the pass-through relationship, this will appear as a structural break. If the test statistics are to be meaningful (that is if the statistics are to have well defined distributions under the null of hysteresis and the alternative of no hysteresis) the estimation equation must allow for structural breaks. The exact nature of the structural break should be derived from the model.

Appendix - A Delivery Lags model of Lagged Exchange Rate Effects

This appendix derives the estimation equation of a structural model of the pass-through relationship which explicitly accounts for lagged exchange rate effects. Delivery lags are a well known source of lagged effects in macroeconomics. The model here is simply a straightforward application. We find it convenient to work with a differentiated products framework where each firm has a monopoly position for its own variety and maximizes profits in terms of dollars.

This model of lags assumes that firm j faces a delivery lag of n_j periods, and a stochastic US demand curve. Period t output is assumed to reach the US market in period $t+n_j$. The firm chooses sales to the US, y_t^j , in each period to maximize the discounted sum of expected profits. Consider the case of $n_j=1$. The problem of firm j is:

$$(2) \max_{\{y_t^j\}} E \left(\sum_{t=0}^{\infty} R^t [R(P_{t+1}[y_t^j]) - c_t^j] y_t^j \right),$$

where P_{t+1} and c_t^j are the dollar price in period $t+1$ (this depends on y_t^j) and the marginal cost (which depends on the exchange rate) respectively, and R is a constant discount factor, $(1/(1+r))$. Adopting fairly standard macro notation for expectations (e.g., $x_t|_{t-1}$ is the expectation of x_t formed at time $t-1$) the typical Euler equation for this problem is:

$$(3) P_{t+1}|_t = \frac{c_t^j}{R(1-1/\epsilon^j)},$$

where ϵ^j is the constant demand elasticity faced by firm j . We have assumed $R(1-1/\epsilon^j)$ is non-stochastic. If different firms face delivery lags ranging from zero to N periods, the aggregate import price index $(P_t = \prod_{j=1}^{\ell} [P_t|_{t-n_j}]^{\theta^j})$ where ℓ is

the number of firms and θ^j is firm j 's weight in the index) will be:

$$(4) \quad P_t = \prod_{j=1}^{\ell} \left[R^{-n_j} \frac{1}{(1-1/\epsilon^j)} c_{t-n_j}^j \right]^{\theta^j},$$

where $c_{t-n_j}^j$ is firm j 's dollar marginal cost in period $t-n_j$. Note that n_j is firm-specific and ranges from zero to the maximum delivery lag length, N .

Taking logs of (4) produces:

$$(5) \quad \log(P_t) = \log \left(\prod_{j=1}^{\ell} \left[\frac{R^{-n_j}}{(1-1/\epsilon^j)} \right]^{\theta^j} \right) + \sum_{i=0}^N \alpha_i \log \left(\prod_{j \in \Psi_i} [c_{t-i}^j]^{\theta^j} \right),$$

where in the last term we have grouped firms according to the length of their delivery lag, i.e., Ψ_i is the set of firms with a delivery lag of i periods. The parameter α^i is the sum of the θ^j 's of the firms with delivery lags equal to i , so $\alpha^i = \sum_{j \in \Psi_i} \theta^j$.

Equation (5) depends crucially on unobservable expectations. To implement (5) empirically we must specify the expectations process in terms of observable variables. To this end we assume firms have rational expectations in the sense that while their expectations may be incorrect, their expectational errors have a mean of zero and are uncorrelated with every thing that was in their information set when they formed the expectation.

This assumption allows us to specify the expectations in terms of observables and at the same time gives us a theory for the time series properties of the error term. Specifically, replacing P_t (the expectations) with the values actually realized, we get:

$$(6) \log(P_t) = \log\left(\prod_{j=1}^{\ell} \left[\frac{R^{-n_j}}{(1-1/\epsilon^j)} \right]^{\theta^j} \right) + \sum_{i=0}^N \alpha_i \log(C_{t-i}) + u_t,$$

where C_{t-i} is an index of individual firm's marginal costs.

Using reasoning that is fairly standard in macro econometrics, the assumption of rationality makes the stochastic properties of u_t easy to establish. Clearly u_t has an expectation of zero, and $E(u_t u_{t-i}) = 0$ for all $i > N$. However $E(u_t u_{t-i}) \neq 0$ for $i \leq N$, due to the presence of overlapping expectational errors. In other words, u_t follows a order- N moving average process.

It is important to note that u_t is not orthogonal to the contemporary regressands, so we must instrument. The assumed rationality provides us with a large set of instruments. Any variable that was in the information set of firms when the expectations were formed is orthogonal to u_t . Thus we have $E(u_t X_{t-i}) = 0$, for all $i > N$, where X_{t-i} is the set of the publicly available variables at time $t-i$.

If we use indices for P and C which are proportional to the true indices, i.e., $P'_t = \delta P_t$ and $C'_t = \nu C_t$, then (5) becomes:

$$(7) \log(P'_t) = \log\left(\lambda \prod_{j=1}^{\ell} \left[\frac{\Omega^j}{(1-1/\epsilon^j)} \right]^{\theta^j} \right) + \sum_{i=0}^N \alpha_i \log(C'_{t-i}) + u_t,$$

where λ is the ratio of ν to δ . Clearly P' must be the real price of imports since demand equations depend on relative prices, and C' must be a measure of real marginal costs measured in the same units as P' .

FOOTNOTES

1. Carmen Reinhart pointed out that the NIA non-oil price deflator is a variable weight index, while the CPI and WPI cost proxies are fixed-weight indices. Since the composition of US imports has been changing, part of the divergence between actual and forecasted may be due to aggregation problems. This cannot be the whole explanation since Mann's work shows that even industry level pass-through equations (where compositional changes are absent) have shifted.

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Figure 1:Forecast errors of pass through equation using WPI data with no lags, estimated on pre-1981:3 data.

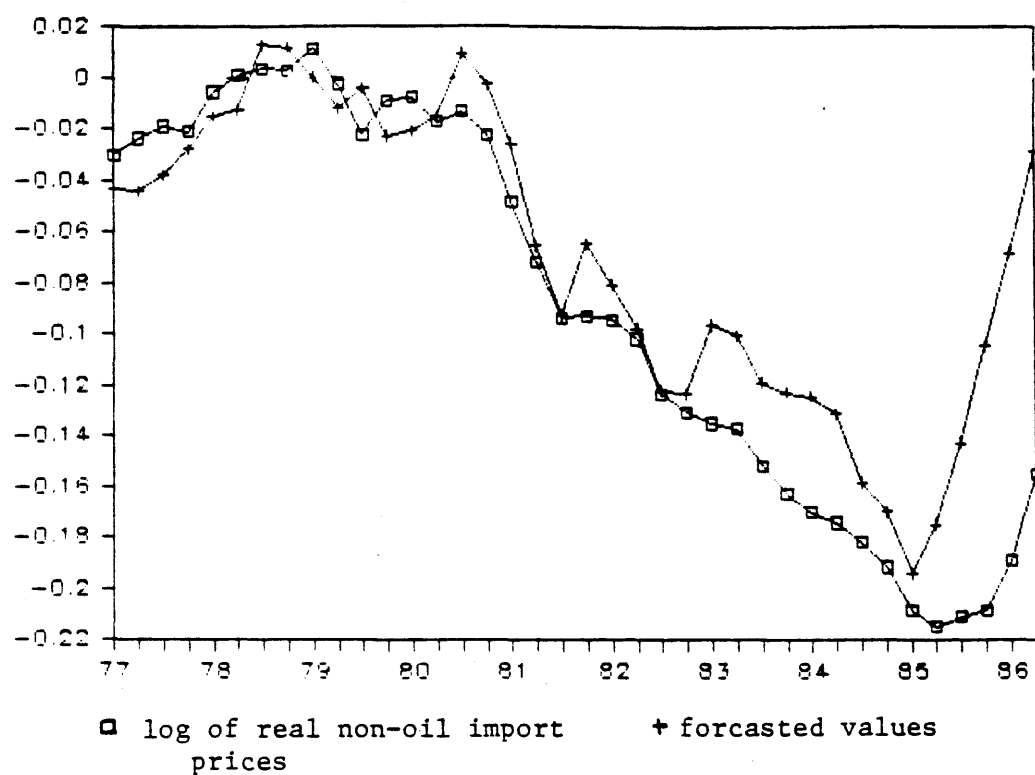


Figure 2:Forecast errors of pass through equation using WPI data with 8 lags, estimated on pre-1981:3 data

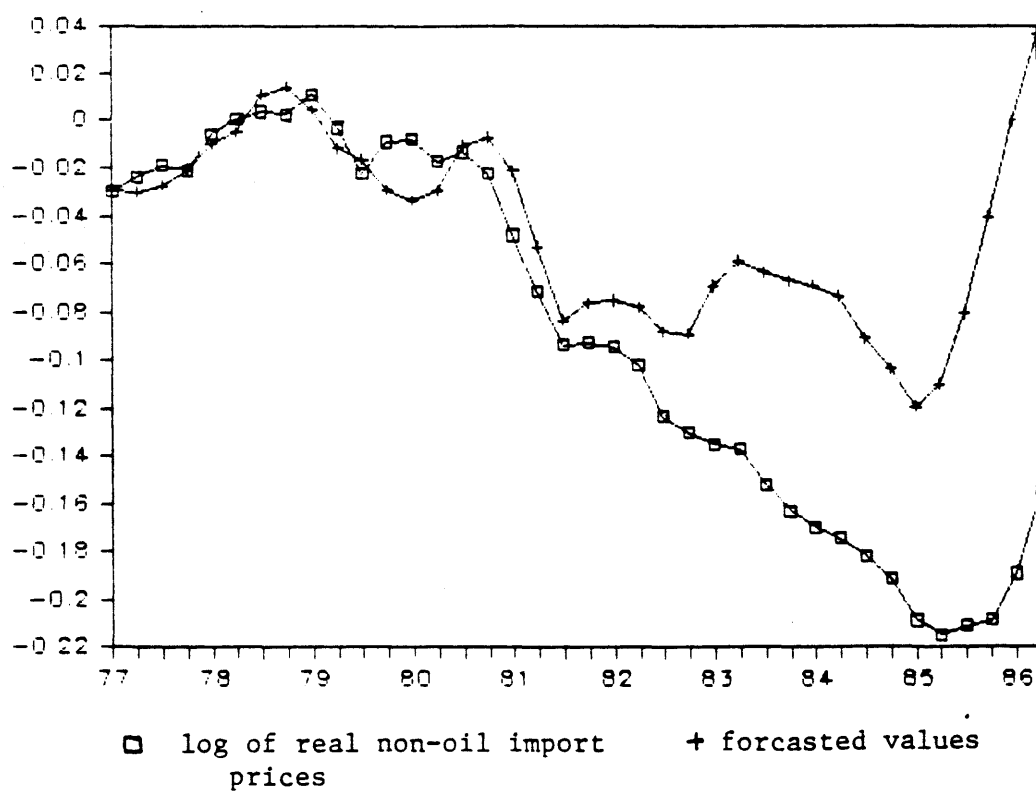


Figure 3: Forecast errors of pass through equation using CPI data with no lags, estimated on pre-1981:3 data.

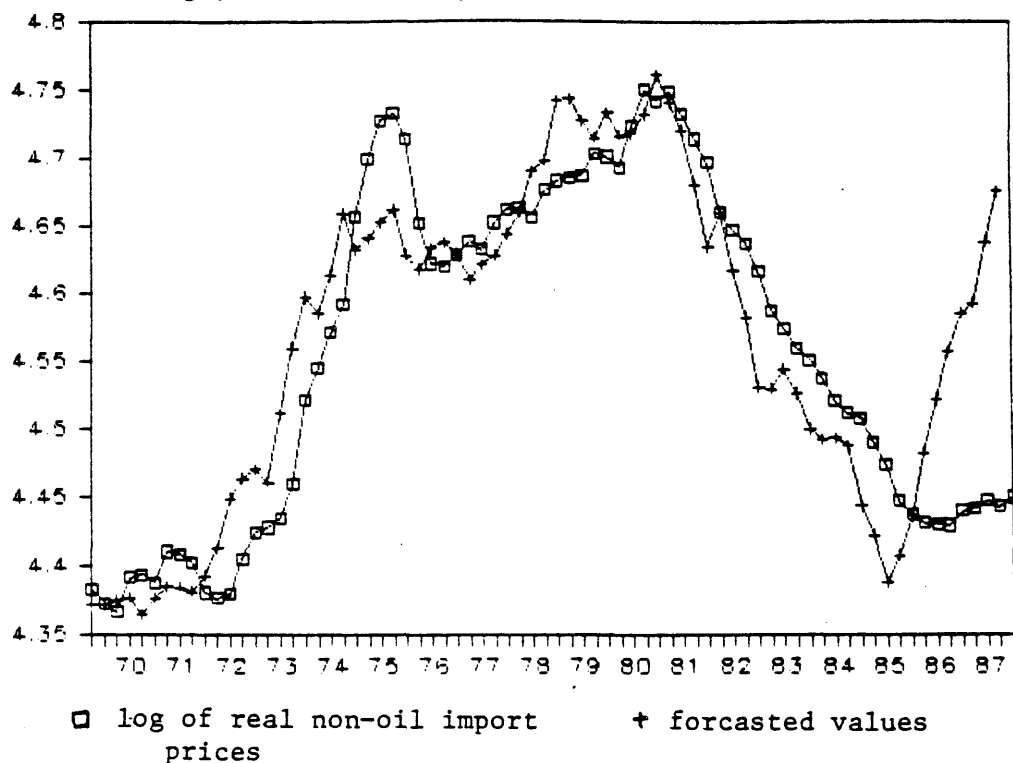


Figure 4: Forecast errors of pass through equation using CPI data with 8 lags, estimated on pre-1981:3 data.

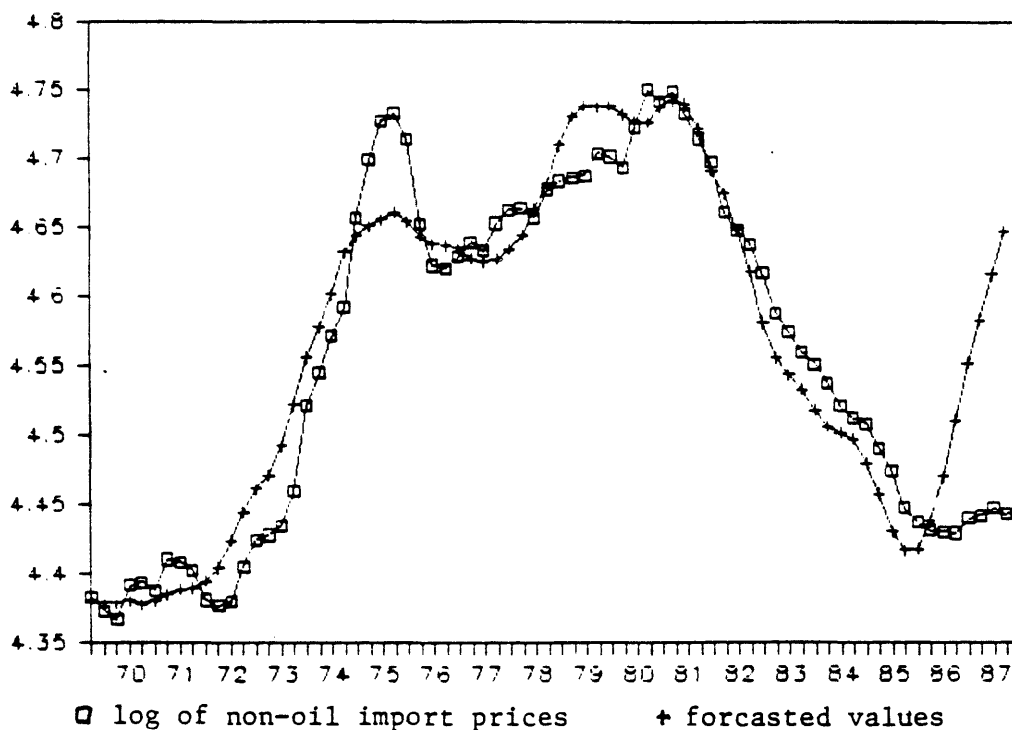


Figure 5: Regression residuals from pass through equation using WPI data with no lags (estimated on 1975:1-1986:2)

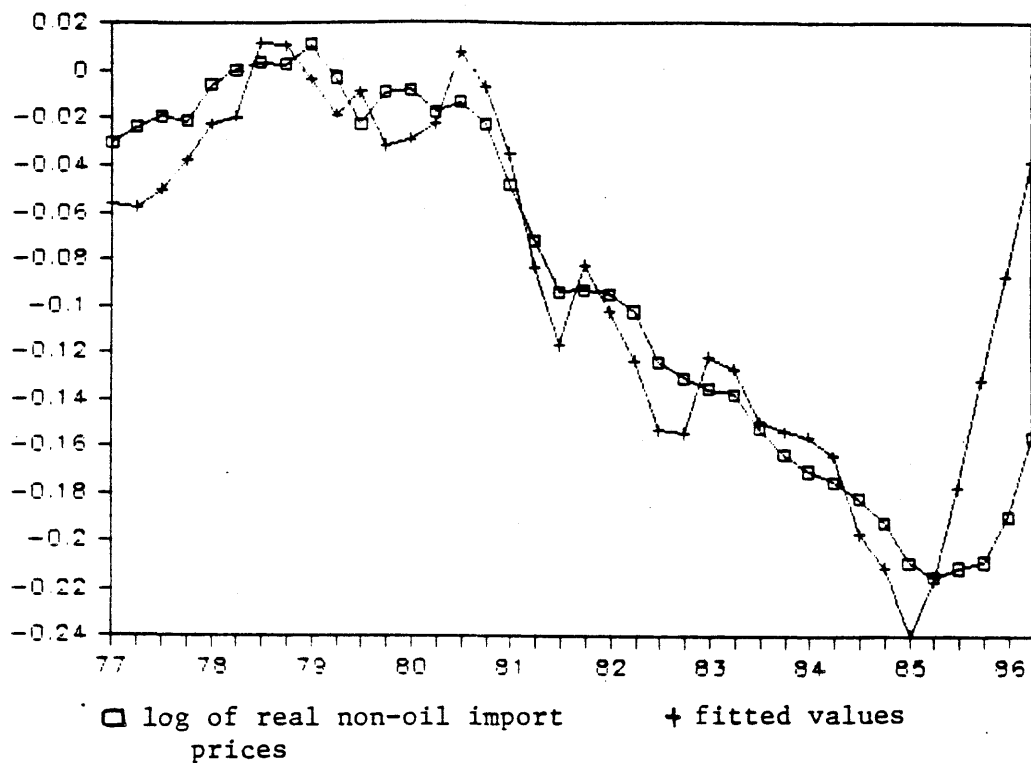


Figure 6: Regression residuals from pass through equation using WPI data with 8 lags (estimated on 1975:1 - 1986:2)

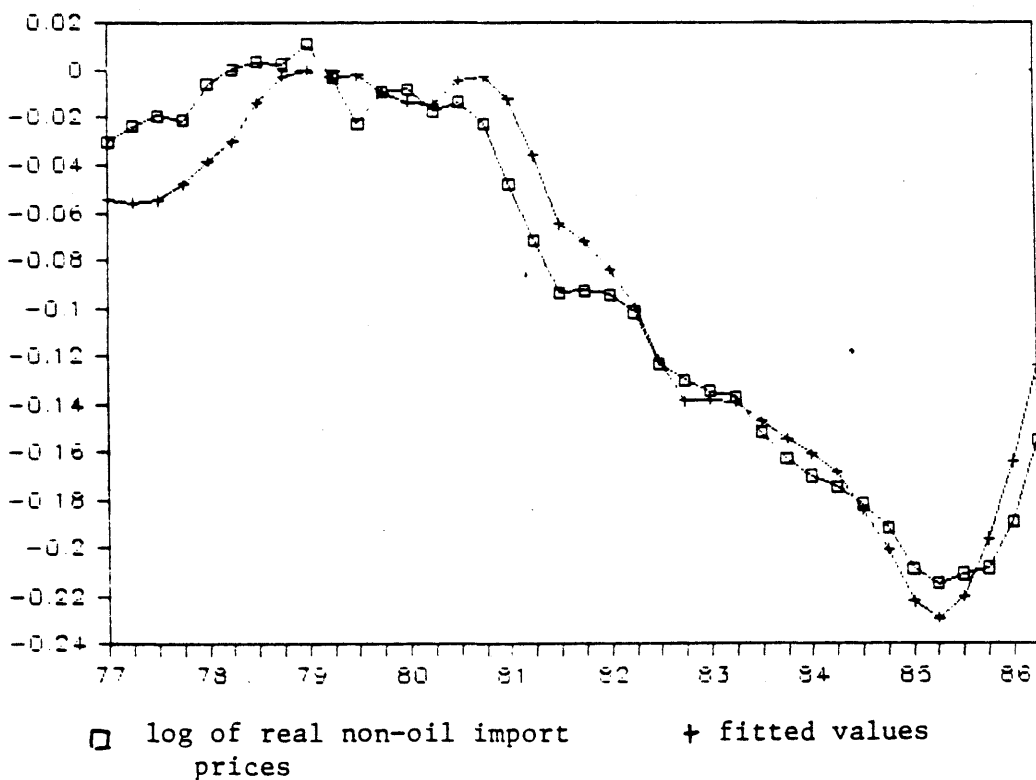


Figure 7: Regression residuals from pass through equation using CPI data with no lags (estimated on 1967:1 - 1987:2)

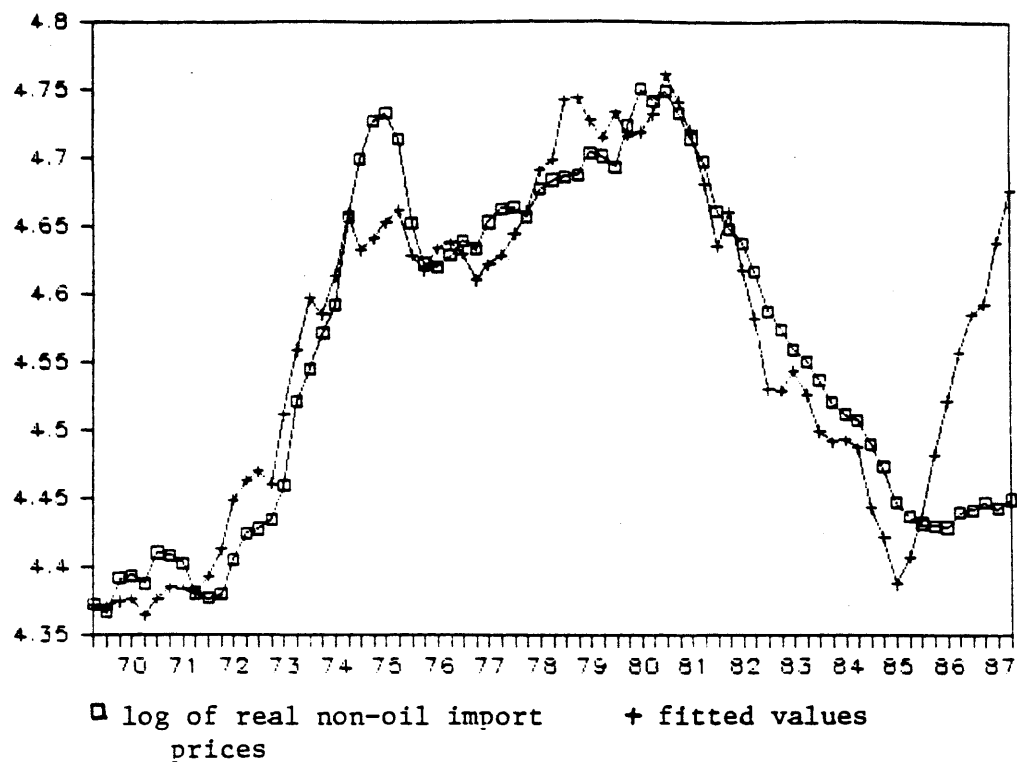


Figure 8: Regression residuals from pass through equations using CPI data with 8 lags (estimated on 1967:1 - 1987:2)

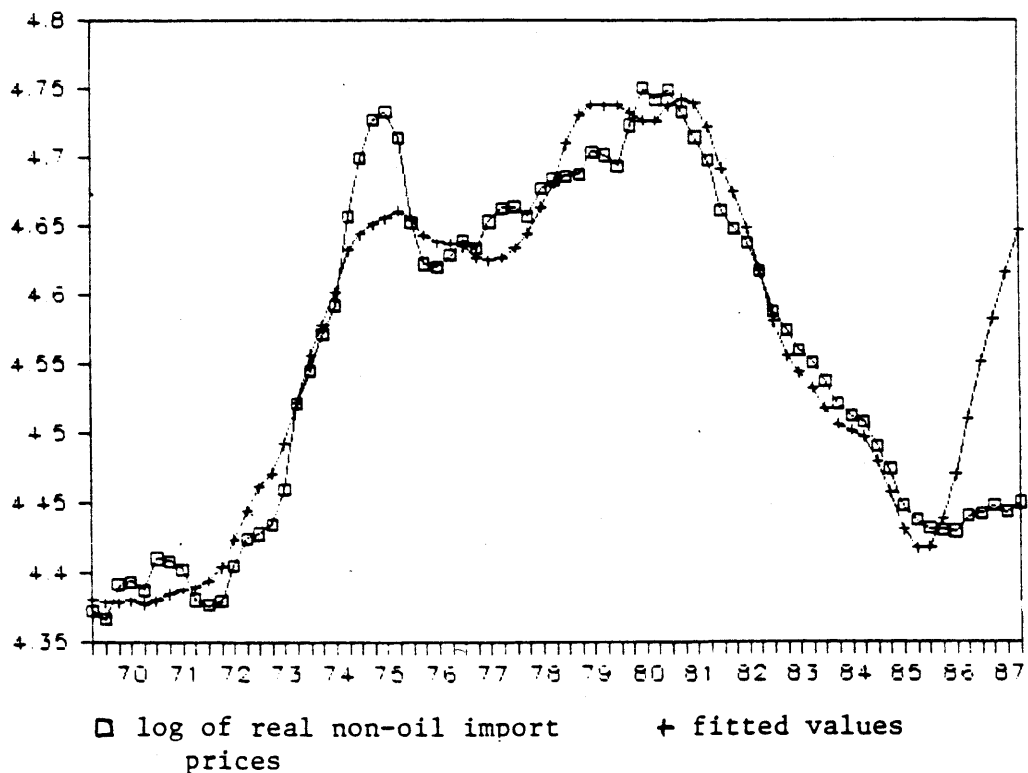


Figure 9: Regression residuals from pass through equation based on nominal import prices and nominal foreign costs (1967:1-1987:2).

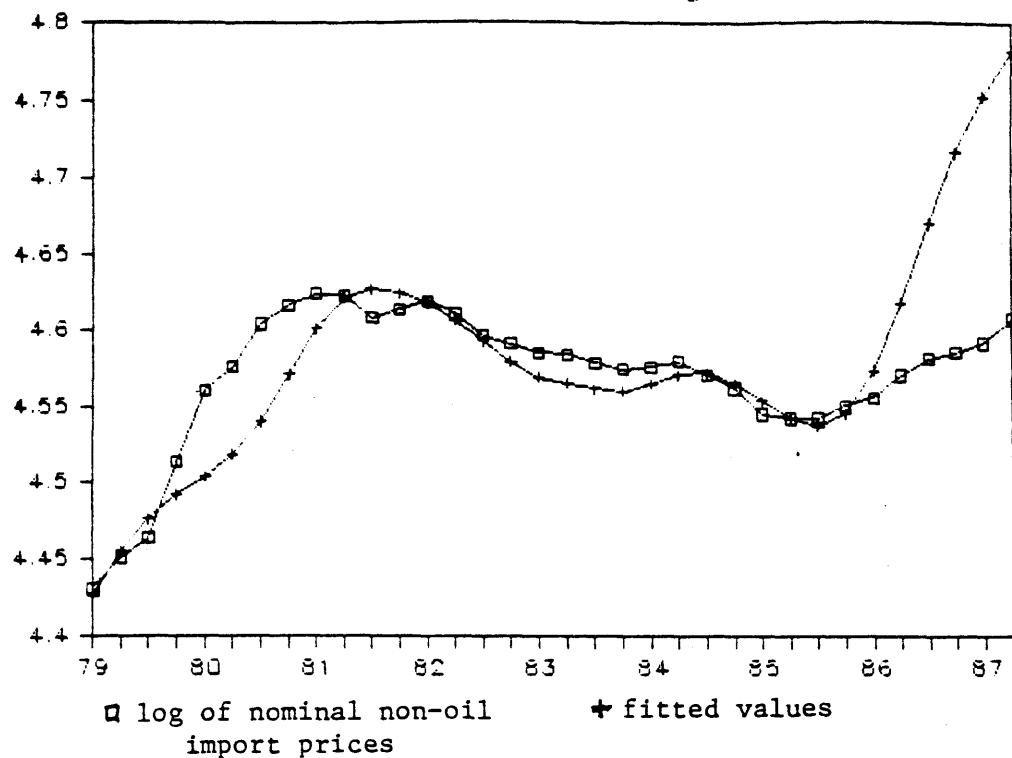


Figure 10: Time varying profit margin, CPI data

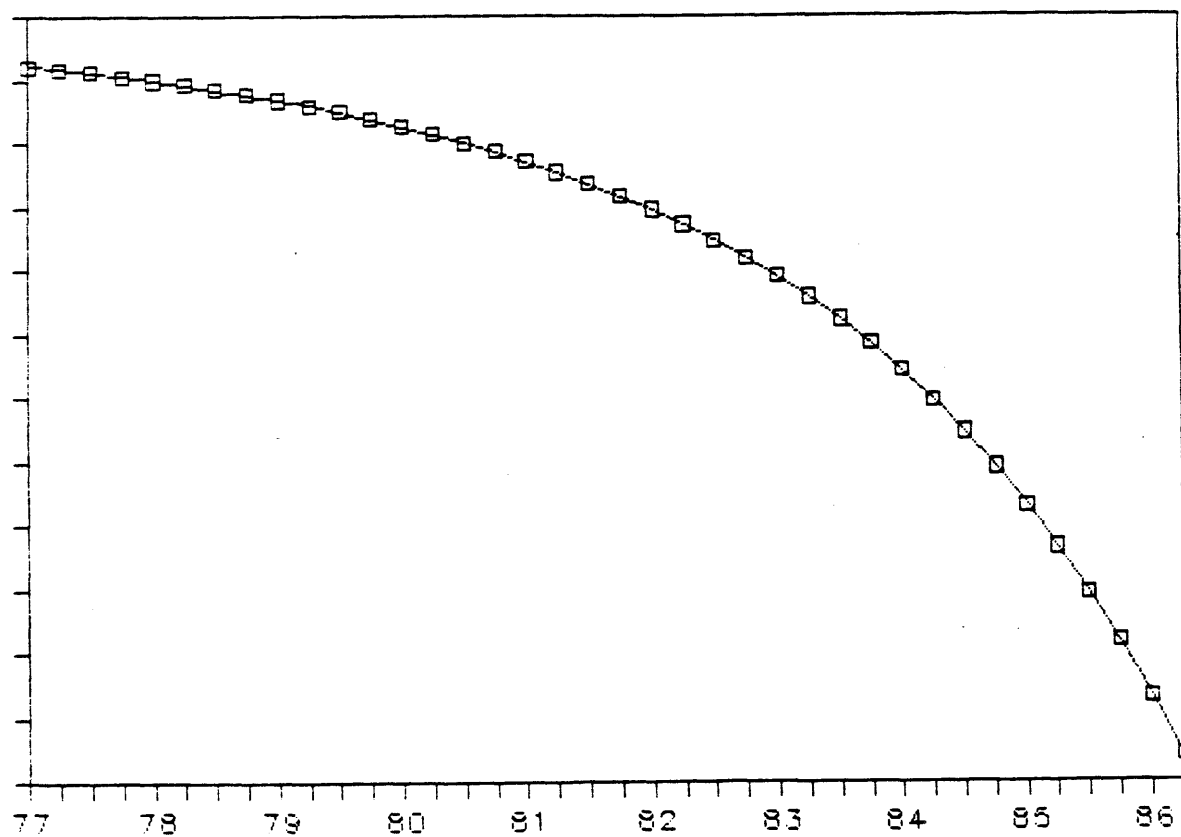


Figure 11: Time varying profit margin, WPI data

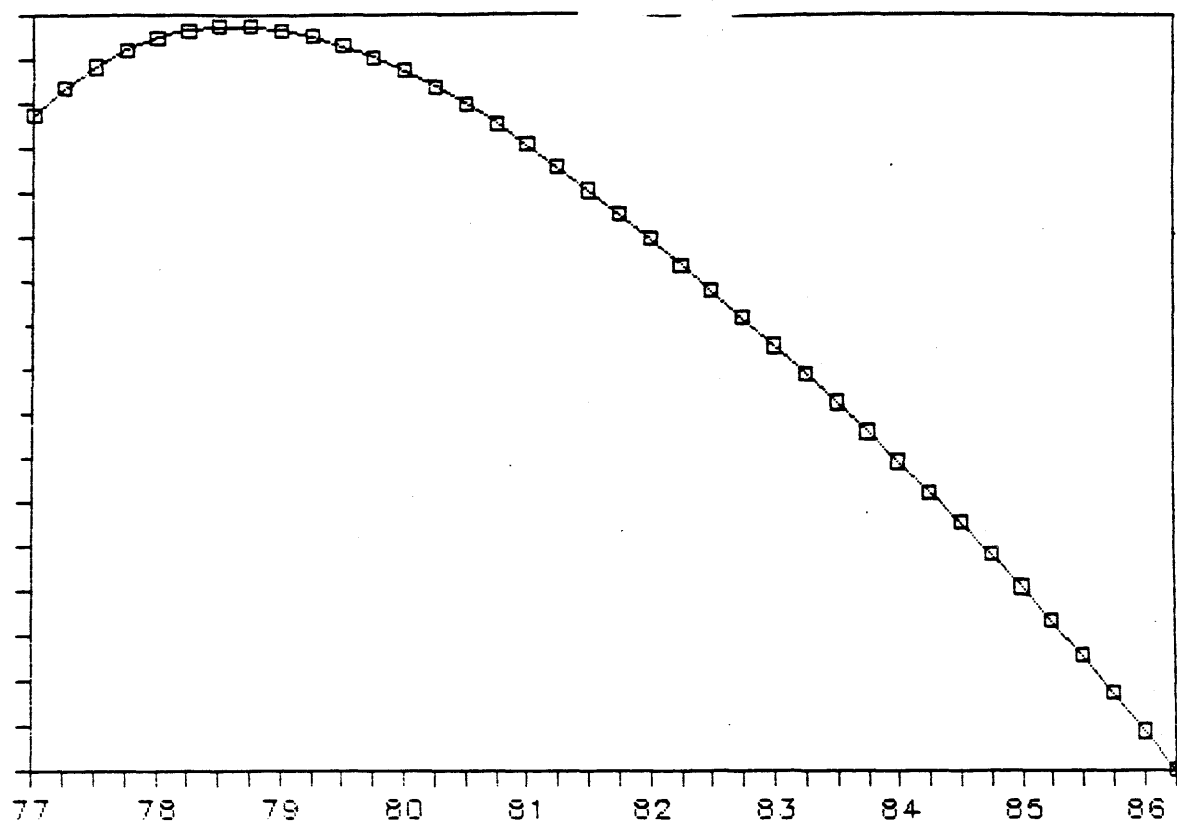


Figure 12: Import volume equation, fitted vs actuals

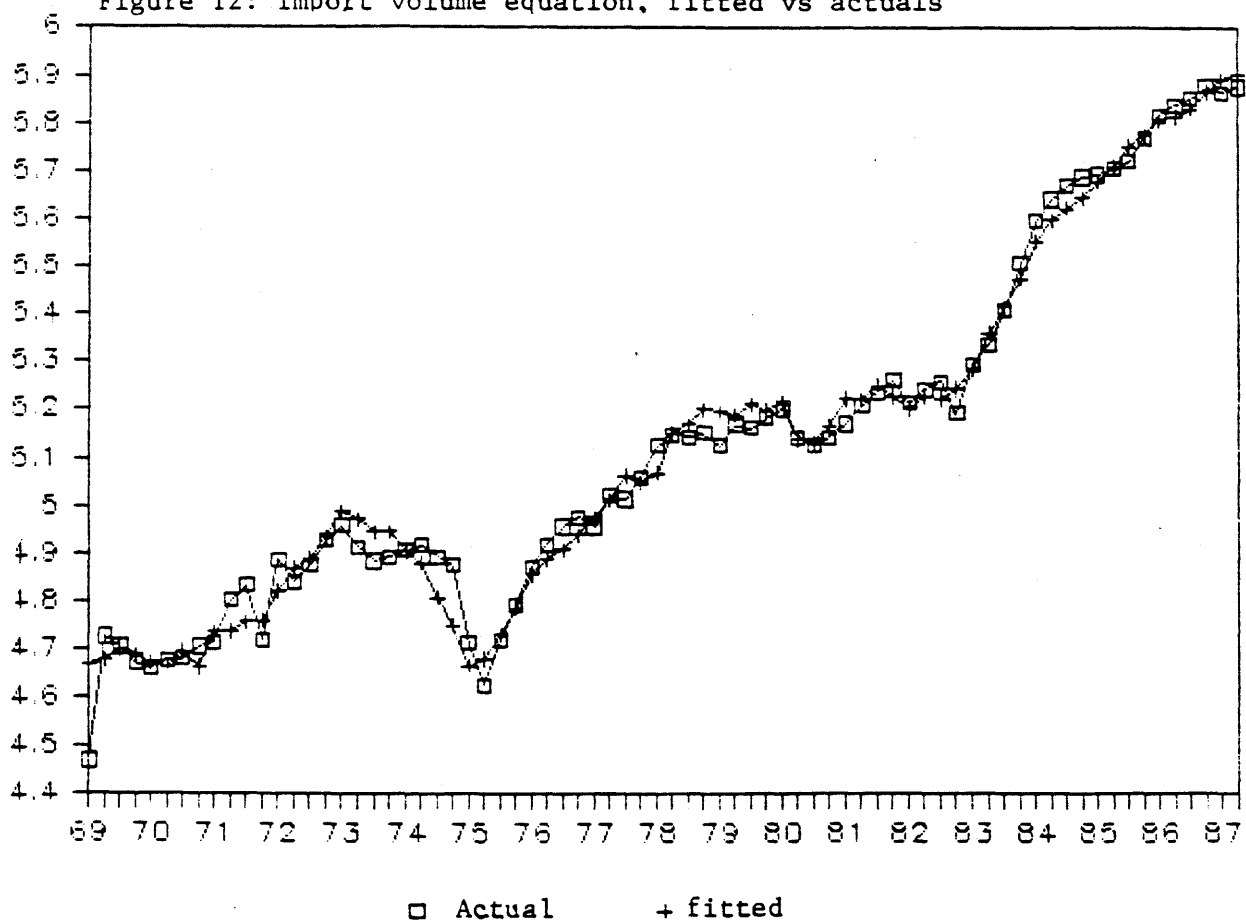


Figure 13: Monopolistic firm's problem with bottlenecks

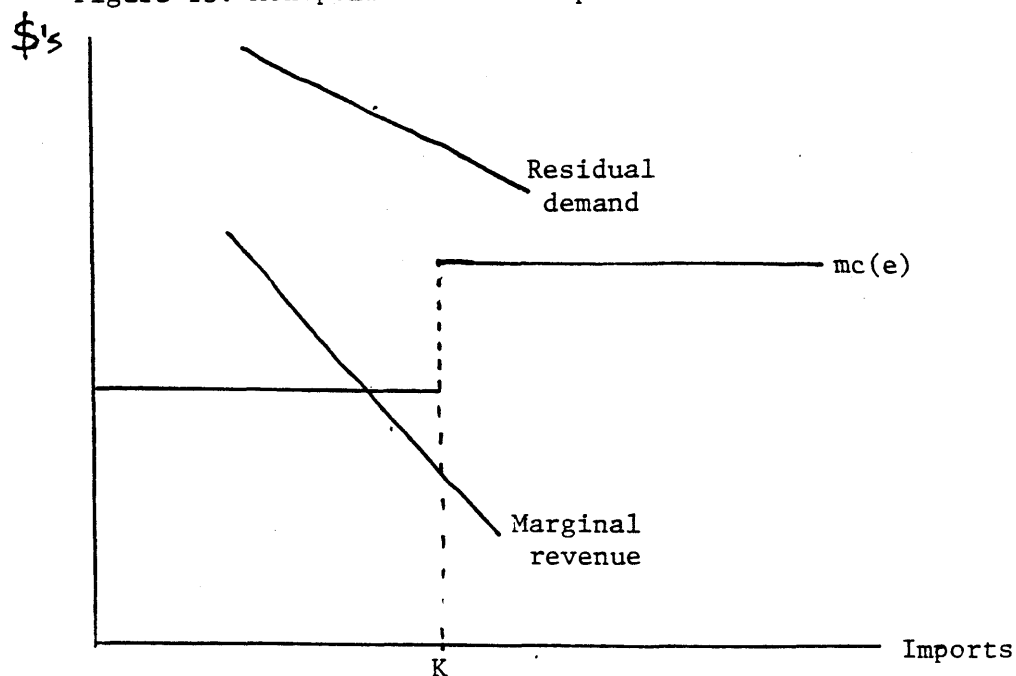


Figure 14: Discontinuous pass through

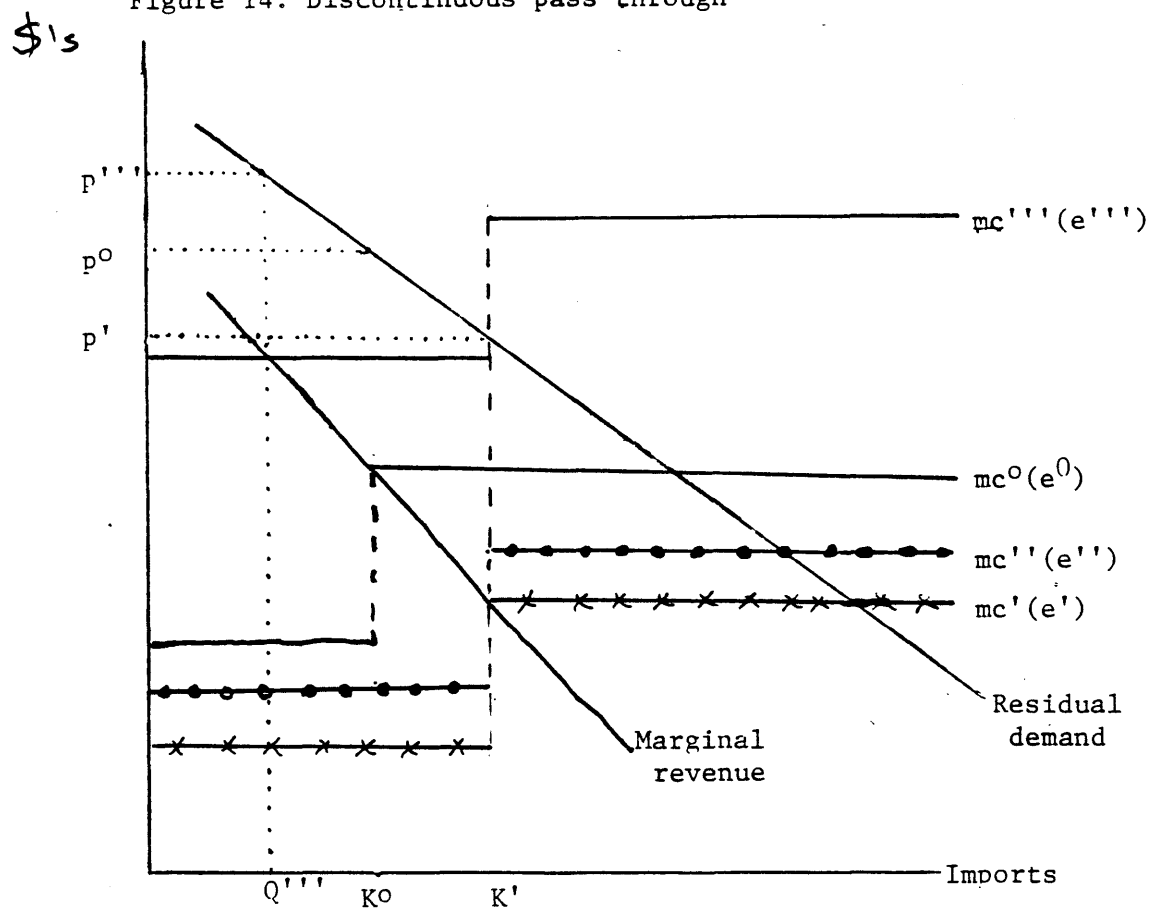


Figure 15: Reversed Asymmetry in the bottleneck model

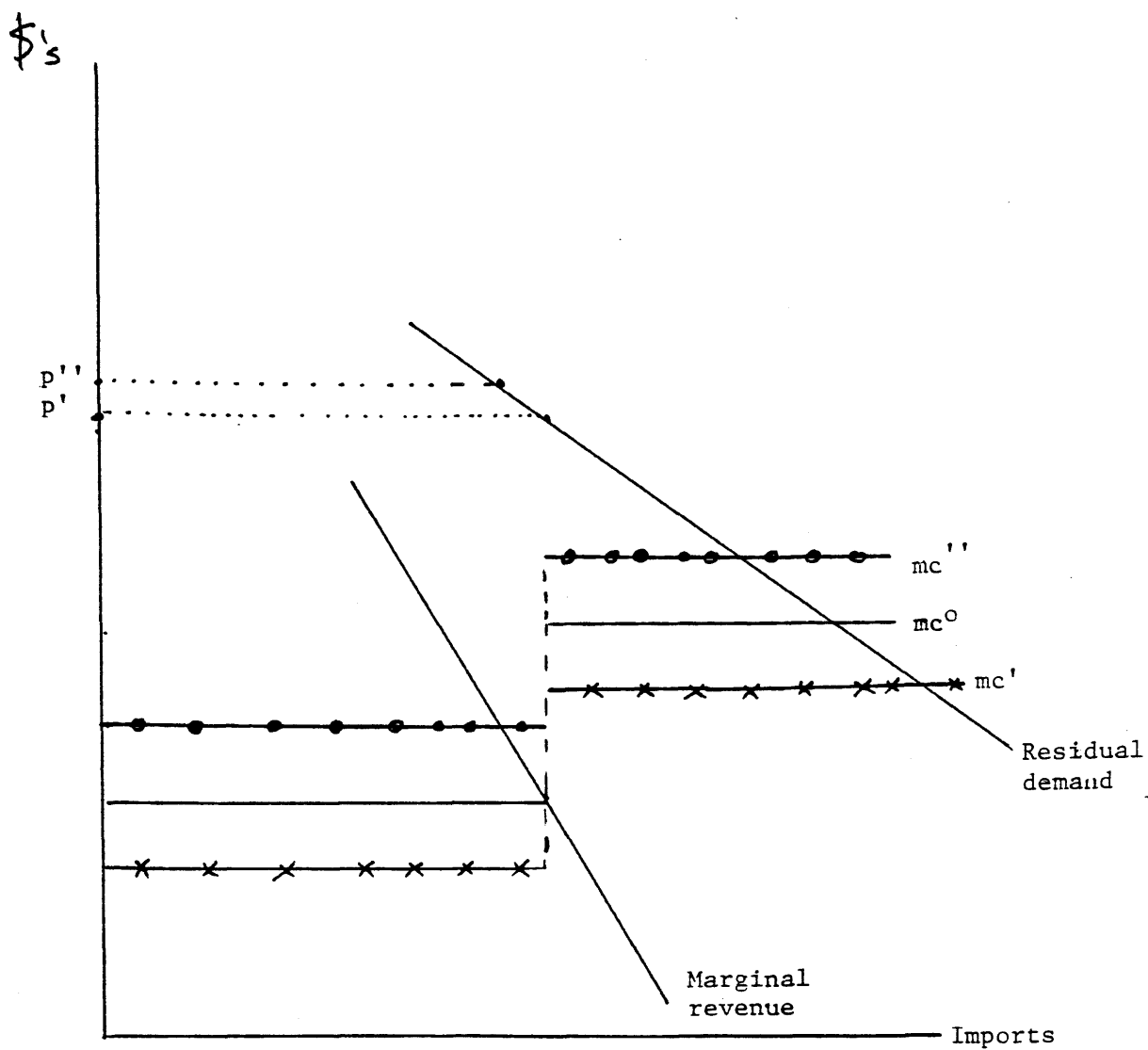


TABLE 1 - Likelihood Ratio Tests for Structural Break on Reduced Form Equations

<u>Model Formulation</u>		<u>Level</u>	DATA			
			CPI data <u>1st Diff</u>	<u>Real</u>	Manf. WPI data <u>Level</u>	<u>Real</u>
	Break Point					
Helkie & Hooper	1980:3	**	-	-	-	-
	1982.1	**	-	-	-	-
	1982.3	**	-	-	-	-
	1983.1	**	-	-	-	-
	1984.1	**	-	-	-	-
	1985.1	na	-	-	-	-
Krugman & Baldwin	1980:3	**	**	**	**	**
	1982.1	**	**	**	**	**
	1982.3	**	**	**	**	**
	1983.1	**	**	**	**	**
	1984.1	**	**	**	**	**
	1985.1	**	**	**	**	**
Mod'd Krugman & Baldwin	1980:3	**	**	**	**	**
	1982.1	**	**	**	**	**
	1982.3	**	**	**	**	**
	1983.1	**	**	**	**	**
	1984.1	**	**	**	**	**
	1985.1	**	**	**	**	**

=====

** indicates no structural break hypothesis rejected at 99.5 %
na indicates test could not be performed due to near singularity in data
- indicates test was not performed

Helkie & Hooper

$\log(p) = c + \log(pform) + pdl(\log(e),8) + pdl(\log(pcom),4) + AR(1)$
pdl indicates that lags were restricted to follow a 3rd order polynomial;
length of lag follows variable name.
p is nominal non-oil import price
pform is an import weighted index of foreign CPI (G-10 and 8 LDCs)
me is the import weighted nominal exchange rate index
pcom is a world commodity price index
first order autocorrelation correction was performed

Krugman & Baldwin

$\log(p) = c + pdl(\log(er),8) + AR(1)$
pdl indicates that lags were restricted to follow a 3rd order polynomial;
length of lag follows variable name.
p is either nominal or real non-oil import price deflator
er is either nominal or real import weighted exchange rate
first order autocorrelation correction was performed

Modified Krugman & Baldwin

$\log(p) = c + \log(pform) + pdl(\log(er),8) + AR(1)$
pform is either a CPI or WPI based import weighted index of either real or nominal foreign prices
er is either nominal or real import weighted exchange rate index

TABLE 2 - Change in Profit Margin at Various Break Points

<u>Model Formulation</u>		<u>Data</u>	
		CPI data	Manf. WPI data
<u>Break Point</u>			
Delivery Lags w/Rat'l Exp'ns.(n=5)	1980:3	↓ **	↓ **
	1982.1	↓ **	↓ *
	1982.3	↓ **	↑
	1983.1	↓ **	↑
	1984.1	↓ **	↑
	1985.1	↓ **	↓
w/Rat'l Exp'ns.(n=4)	1980:3	↓ **	↓ **
	1982.1	↓ **	↓ *
	1982.3	↓ **	↑ *
	1983.1	↓ **	↓
	1984.1	↓ **	↓ *
	1985.1	↓ **	↓ *
w/Rat'l Exp'ns.(n=3)	1980:3	↓ **	↓ **
	1982.1	↓ **	↓ *
	1982.3	↓ **	↑
	1983.1	↓ **	↓
	1984.1	↓ **	↓
	1985.1	↓ **	↓ **

=====

↓ indicates that intercept dummy is negative implying that perceived demand elasticity increases after break point (i.e., profit margin falls)

↑ indicates that intercept dummy is positive implying that perceived demand elasticity decreases after break point (i.e., profit margin rises)

** indicates no change in constant term hypothesis rejected at 99.5 % level

* indicates no change in constant term hypothesis rejected at 95 % level

Delivery Lags Pass Through Equation:

$$\log(p_t) = c + \text{dummy} + \sum_{i=0}^n \gamma_i \log(\text{rer}_{t-i}) + \text{MA}(n),$$

where p_t is the real import price, dummy is an intercept dummy starting at t break point listed, and rer_{t-i} is the real exchange rate at t-i. MA indicates that the error was assumed to follow a moving average process of order n.